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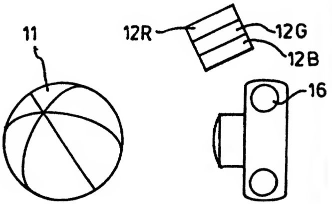
(54) Title: PRODUCING OR CHARACTERISING COLOUR IMAGES AND MEASURING COLOUR

(57) Abstract

There is disclosed a method of extracting information from an object or object scene comprising illuminating the object or scene by a plurality of primary colour illuminants and measuring or recording the resulting light from the object or scene.



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PRODUCING OR CHARACTERISING COLOUR IMAGES AND MEASURING COLOUR

This invention relates to producing colour images, such as colour images which are also precise colorimetric definitions of the object or scene being imaged, and also to measuring colour.

Colour images are produced conventionally in a variety of ways. Colour photography records an object scene on red, green and blue (RGB) dye layers in an emulsion for viewing as a photograph or for projection as a slide or movie film. Colour video images are produced by excitation of red, green and blue phosphorescent areas to achieve additive mixing and colour reproduction.

True colour reproduction is problematical, depending on such factors as the illumination of the object scene, the nature of the dyes, the exposure and the subsequent processing in colour photography, as well as the colour temperature of the projector lamp, while colour video images, though they can be calibrated, are inherently unstable both in intensity and chromaticity. Colour video has a further disadvantage inasmuch as large (cine screen size), bright images are impossible (or impossibly expensive).

Colourimetry is conventially carried out by illuminating a test object with a standard source of white light, or at least a white light source of constant or reasonably constant characteristics, and measuring the resulting light from the object through a system of filters that each pass a narrow band of optical wavelengths.

Alternatively, colour may be analysed by examining reflectance at a number of wavelengths of the spectrum. A full spectrophotometer may use forty or more wavelengths; an abridged spectrophotometer may use far fewer wavelengths.

It is generally acknowledged that there is poor inter-instrument agreement in present day colour measuring instruments, and this can be attributed to inadequacies in the white light sources and filters or spectral analysis systems currently available.

The present invention provides methods for producing or characterising colour images and for measuring colour not subject to these problems.

The invention comprises a method.of extracting information from an object or object scene comprising illuminating the object or scene by a plurality of primary colour illuminants and measuring or recording the resulting light reflected by or transmitted from the object or scene.

One aspect of the invention comprises a method for producing or characterising a colour image of an object scene in which the scene is illuminated by or recorded by reference to a plurality of primary colour illuminants to record colour separate images for subsequent recombination into a true colour image of the object scene by illumination of each with its respective primary colour illuminant, or by one of a set of equivalent illuminants.

The illuminants may comprise lasers, which are inherently stable as to colour (chromaticity) and which can be precisely controlled, for example by rapid pulsing with variable mark/space ratio, for intensity.

By using primary colour illuminants, whose colour is both known and reproducible with great precision, benefit is derived in the capture, storage, measurement, analysis, transmission and reproduction of colour information.

Each element of the image represents a precise measurement of the object or scene imaged. Full colorimetric definitions are thus available for storage, analysis and transmission. If it is desired to reconstruct the scene the process of capture is reversed using the same illuminants.

Three primary colour illuminants may be used - human colour vision is trichomatic in nature, making RGB colour reproduction possible. The human colour response can be defined and modelled by tristimulus values, for example values based on the widely accepted CIE system of colour measurement. It is then possible to encode a high proportion of colour information with just three RGB signals, but it is also potentially valuable to be able to encode and transmit multi-line spectrophotometric definitions of colour, say with 16 or 40 spectral lines, and the method can encompass such definition.

The colour separate images may each be recorded while the object scene is illuminated by only one of the illuminants. Three separate monochrome photographs

can be taken e.g. of a still life scene, each using a different illuminant. Separate video frames can be recorded using synchronised RGB illumination.

The colour separate images could, however, be recorded while the object scene is illuminated by more than one (or all) of the illuminants and the images separated by filtration. Thus a cine film could comprise three side-by-side images to a frame taken through three taking lenses each with an appropriate colour filter - here the colour filter is not intended to provide the colour definition, merely to block the unwanted light from the other illuminants.

A prism could be used as a filter, however, separating RGB images from a single taking lens into three imaging areas of a cine film frame, or even of a video camera's CCD array.

It is important to note that the images are stored as monochrome information, representing information about the scene at discrete, well separated wavelengths, whether on photographic emulsion or as digitised grey-scale electronic recordings. True colour reconstruction is achieved by projecting the images using the same illuminants as were used to make the recorded images, or to which the stored images are referenced.

An important feature of this method of image capture is that it captures and stores a precise colorimetric description of all colours that are imaged. The colorimetric description in the form of monochromatic reflectance values referenced to precisely

defined primaries can be transformed into CIE colour specifications by direct calculation. The scene or object is both imaged and measured at the same time.

Transparency images can, of course, be projected in the usual way. If RGB lasers were used to illuminate the object scene, the same lasers would be used as projector lamps, the optical system recombining the projected images on the screen.

An electronically captured image may be projected in various ways. One such way is by scanning modulated illuminant beams, as by a controlled mirror arrangement.

The invention also comprises apparatus for producing a colour image of an object scene comprising a plurality of primary colour illuminants and recording means for colour separate images for subsequent recombination into a true colour image of the object scene by illumination of each with its respective primary colour illuminant.

Another aspect of the invention comprises a method for measuring colour comprising illuminating a test object with laser light of different wavelengths and measuring the resulting light from the test object.

The test object can be an opaque solid object or a surface thereof, or a transparent or translucent solid such as glass or plastic, or a liquid or indeed anything through which light can pass or from which it can be reflected or scattered. The light measured can be reflected, scattered or transmitted as appropriate.

Three or more laser light frequencies may be used in the measurement, which may be in the blue, green and red spectral regions.

The test object may be illuminated, and the resulting light measured, simultaneously by two or more of the laser light wavelengths. The test object may, however, be illuminated and the resulting light measured successively by individual laser light wavelengths.

The test object may also be illuminated by light outside the optical spectrum (which may be laser generated) and any resulting secondary emission, for example for ultra-violet light, measured, either alone or in combination with visible reflected light.

Both incident and resulting (e.g. reflected) light beams may be measured, so that the resulting light can be measured as a fraction of the incident light, which will compensate for any variability in intensity of the incident light.

Calibration may be made by measuring zero illumination and 100% (i.e. direct to the measuring device or via a white reference standard) illumination.

Measurement may be made with the brightness of each laser light source remaining the same relative to the other laser light sources, or the brightness of at least one laser light source may be varied as compared to that of another, which may allow for measurement under different colour temperature conditions.

Light from at least one laser light source may be guided to a measuring point by an optical fibre. Light from the test object may be guided to a measuring device by an optical fibre. Measurement may be made at two or more locations by optical fibres terminating at those locations.

The method may be used as an element of a colour control process. Light from a test object illuminated by laser light may be used in a feedback loop.

The use of lasers, which have reasonably stable, mono-chromatic outputs, eliminates the variability of the white source used in conventional colourimetry. It also eliminates possible variations in the colours of filters used in such colourimetry.

The invention also comprises colour measurement apparatus comprising laser illuminant means capable of emitting different wavelengths and light measuring means measuring light from a test object illuminated by said illuminant means.

The apparatus may comprise three or more laser illuminants of different wavelengths, which may be in the blue, green and red spectral regions, or a single tunable laser may be used in place of any two or all three. The apparatus may also comprise an ultraviolet illuminant, which may also be a laser.

The apparatus may comprise individual channels for each wavelength, or a common channel might accommodate two or more wavelengths. The apparatus might comprise time sequencing means for different wavelengths sharing a channel.

Channel means for one or more wavelengths may comprise optical fibre means.

Optical fibre means may distribute measuring light from a common source to a plurality of measuring points and/or from a plurality of measuring points to common measuring means.

The invention also comprises colour control means comprising novel measuring apparatus as herein defined. The measuring apparatus may be part of a feedback loop in, for example, a fabric dyeing, paint mixing or other colouring operation in which any departure from a desired colour is detected and compensated for.

Embodiments of apparatus and methods for producing colour images according to the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic illustration showing a simple apparatus set up for recording primary colour separate images;

Figure 2 is a diagrammatic illustration showing an image display system for the apparatus of Figure 1;

Figure 3 is a diagrammatic illustration of another apparatus adapted for recording primary colour separate images;

Figure 4	is a diagrammatic illustration of yet another apparatus adapted for recording primary colour separate images;
Figure 5	is a diagrammatic illustration showing a video recording system;
Figure 6	is a diagrammatic illustration of a first video playback system;
Figure 7	is a diagrammatic illustration of a second video playback system;
Figure 8	is a diagrammatic illustration of a third video playback system;
Figure 9	is a diagrammatic illustration of a fourth video playback system;
Figure 10	is a diagrammatic illustration of a first measuring apparatus;
Figure 11	is a diagrammatic illustration of a second measuring apparatus;
Figure 12	is a diagrammatic illustration of a third measuring apparatus;

Figure 13 is a diagrammatic illustration of a fourth measuring apparatus; and

Figure 14 is a diagrammatic illustration of a colour process control arrangement.

The drawings illustrate methods of and apparatus for extracting information from a test object or object scene 11 by illuminating the object or scene 11 by a plurality of primary colour illuminants 12 and measuring or recording the resulting light from the object or scene 11.

Figures 1 to 9 of the drawings illustrate methods and apparatus for producing a colour image of an object scene 11.

For recording the image, the scene 11 (Figures 1, 3, 4 and 5) - here shown as a multicoloured beach ball - is illuminated by a plurality - here three - of primary colour illuminants 12R, 12G and 12B (for red, green and blue light) to record colour separate images 13R, 13G and 13B for subsequent recombination into a true colour image 14 of the object scene 11 by illumination each with its respective colour illuminant 15R, 15B and 15G (Figures 2 and 6-9).

If it is desired to determine precise colorimetric information of the object being imaged, then reference materials with known high and low reflectance may be included in the image. By referring to the image values of these references, image values for the rest of the image may be converted into true colorimetric specifications. These

specifications may in turn be used for colorimetric analysis, and surface colour reproduction by various methods including printing and photographic means.

The illuminants 12R, 12B, 12G, 15R, 15B and 15G are all shown as separate light sources, for which lasers will clearly be eminently suitable because they give a stable, readily controllable, single frequency light emission. The coherent nature of laser light is not of major significance in connection with the present invention, but may be useful in certain applications.

Clearly, however, any other source of light that is or can be controlled to be stable and which is monochromatic or substantially so can be used in place of a laser, for example a simple source of white light may be filtered or may be spread by a prism or grating into its different component colours and narrow frequency bands of colour taken out using an optical system or optical fibres. Further, the principle of obtaining coloured image information by combining three or more monochromatic images may be achieved by optical filtering methods, in so far as it is possible to filter out all light other than a single monochromatic component. This applies to both the imaging process and the reproduction process. Clearly, too, the apparatus will yield colour images even if the illuminants used for displaying the image are different from those used for recording the image. Usually, however, it will be possible and indeed found most convenient to use lasers for both recording and display because then the colour reproduction can be precise. The recording and displaying illuminants can, of course, be of different powers depending on the degree of illumination required at the object for recording purposes and the size and required brightness of the displayed image.

And, while three RGB primary colour illuminants have been described, more than three can clearly be used, perhaps as many as forty, for special purposes. Three will suffice, or usually suffice, for normal colour image reproduction. There may even be occasions when, perhaps because of limited colour in the object scene, two illuminants will suffice.

Figure 1 illustrates a simple way of taking colour photographs without using colour film. A conventional camera 16 loaded with black and white film is set up to photograph the object scene 11 which is first lit with red light from laser 12R. The film is wound on then to take the same picture but lit by laser 12B, then the next frame is taken in green light from laser 12G. The film is processed to produce diapositive images 13R, 13G and 13B, Figure 2, which are projected through suitable optics 17 on to a screen 18, using lasers 15R, 15B and 15G as illuminants, the optics 17 forming the three colour separate images in register on the screen 18.

Figure 3 illustrates another method for forming the colour separate images in which the object scene 11 is illuminated by all three lasers 12R, 12G, 12B simultaneously. The camera 16 has three taking lenses 19R, 19B, 19G forming side-by-side colour separate images 13R, 13B, 13G on the film (black and white, again, of course). In front of each taking lens is a colour filter 21R, 21B, 21G. This arrangement is clearly suitable for cine applications using appropriate projection arrangements - note, the projection arrangements do not require the colour filters 21R, 21B, 21G which are used in the camera merely to block off, from each image, light from the lasers not appropriate to it.

Also suitable for cine applications is the image recording arrangement illustrated in Figure 4 in which the colours are "filtered" into different imaging areas by a prism 22, requiring only a single taking lens 19.

As laser light is monochromatic, chromatic aberration should be substantially eliminated which may not only of itself improve image sharpness but will allow lenses to be designed more specifically with other aberrations in mind.

The photographic (strictly speaking, in this context, photo chemical) arrangements thus far described with reference to Figures 1-4 can be applied equally, mutatis mutandis, to arrangements in which image recording is photoelectric as by a video camera or a CCD array.

Figure 5 illustrates an arrangement where a video camera 51 images the subject scene 11 illuminated by lasers 12R, 12B and 12G. A control unit 52 fires the lasers 12R, 12B and 12G synchronously with the camera taking video frames, so that red, blue and green colour separate images are interleaved in the recording.

The video camera 51 may, of course, be a "still" video camera when, clearly, the three colour separate images can be digitised and stored in frame stores. Any manipulation or enhancement processing may be carried out on such digital images and the information, which will be, for each pixel, true tristimulus colour definition, can be extracted. Thus this relatively easily carried out technique can give valuable colorimetric information about any object scene. Such an arrangement will be of great value in textiles, where it will yield accurate colour values for even the most complicated, multi-colourway designs and fabric textures, and also in medicine, where diagnosis may be

based on colour.

However, the camera 51 may be used to record moving images, enabling spectrophotometric information to be extracted from selected image areas at selected times or monitoring, perhaps, colour changes over time.

Copious amounts of digitised spectrophotometric information can be made manageable by compression techniques.

Of course, even without digitisation, the still or moving video image can be reproduced as a true colour displayed image in various ways.

Figure 6 shows an arrangement in which the images 13R, 13B and 13G are displayed on three adjacent liquid crystal transmission screens each projected via suitable optics 61 on to a screen 62 by lasers 15R, 15B and 15G to form superposed images to make a true colour reproduction of the object scene. This can be a "still" arrangement in which images from three frame stores in the video equipment 63 are sent to the liquid crystal screens, or a moving picture arrangement in which sequential images 13 are displayed.

Figure 7 shows an arrangement where the lasers 15R, 15B, 15G are controlled to fire synchronously with the appropriate image 13R, 13B, 13G being displayed on a single liquid crystal transmission screen 71.

Figure 8 shows an arrangement in which the three lasers 15R, 15B, 15G are controlled as to intensity by e.g. digitised information derived from separate electronic colour images in a control arrangement 81. Light from the lasers is deflected to scan over the screen 81 by deflecting mirror arrangements 83 much as the three electron beams of a colour video tube are deflected over its screen to build up an image, the scanning rate being the same so as to present a solid picture to the eye.

Figure 9 illustrates the use of a Digital Micromirror Device(DMD) 91 which comprises a monolithic, micromechanical spatial light modulator that integrates discrete, tilting mirror elements with CMOS addressing circuits at each addressing location, as manufactured by Texas Instruments of Dallas, Texas.

Each micromirror 92 of this device is capable of extremely rapid tilting between two stable positions so as to be able selectively to direct light at a screen to produce an image, the intensity of any image pixel being controlled by pulse width modulation. Light from three lasers 15R, 15B, 15G is directed at the device 91 so as to be directed, by each mirror in its "on" position, at the appropriate pixel area on the display screen 93. The mirrors 92 are controlled by a control unit 94 in accordance with the recorded image information. Three colour separate images can be handled in discrete parts of the screen each illuminated by one only of the lasers, or individual mirrors can be coated with red, blue or green filter material so that the entire device may be illuminated with "white" laser light, the mirrors reflecting only one of the three colours each.

Other arrangements are possible. For example, a "white" laser emitting many individual lines may be attached to an acoustic optic modulator and output slit such that individual lines are projected sequentially, the monochrome imaging (or display) device being synchronised with the modulator to capture (or display) an image for each wavelength.

An image based on many individual spectral lines can be processed with tristimulus specifications for a range of illuminants and displayed on conventional imaging devices - in this way, true colour reproduction can be achieved even though the replay illuminants are different from the recording illuminants - the replay illuminant set will be equivalent to the recording illuminant set in this case.

Figures 10 to 14 of the drawings illustrate methods and apparatus for measuring colour, in which a test object 11 is illuminated with laser light of different wavelengths and the resulting light from the test object 11 is measured.

"Test object" as used herein is intended to encompass anything of which the or a colour is to be measured, and a test object can thus comprise any solid object or a surface thereof, or a liquid or a surface thereof, which may be viewed by reflected or scattered light; or it might encompass a translucent or transparent object such as glass, or a liquid which can be observed by transmitted light, or even a gas or vapour.

Figures 10 and 11 illustrate arrangements in which three laser light wavelengths are used, emanating from three different lasers 12B, 12G, 12R, emitting wavelengths in the blue, green and red spectral regions respectively.

The arrangement of Figure 10 is, or can be, fairly basic. The lasers 12B, 12G, 12R direct narrow coherent beams of blue, green and red light respectively at a point on the surface of the test object 11 and the light that is reflected or scattered by the said surface is picked up by three photodetectors 115, 116, 117 respectively, each picking up one and one only of the colours by virtue of being sensitive only in the blue, green or red regions respectively or by having filters associated with them that blank out light from the other two colours.

It has been suggested that the present invention obviates dependence on colour filters, and it may be noted that all that is required of filters in the embodiment just described is that they block light in spectral regions far removed from those which they pass. It is possible, therefore, to rely on even inexpensive filters, since the filtration requirement is, in the presence instance, coarse. It goes without saying, of course, that ambient illumination should be excluded.

The output of the pohotodetectors 115, 116, 117 which is indicative of the extent to which the test object 11 reflects or scatters the three primary colour frequencies omitted by the lasers 12B, 12G, 12R is fed to a processor 118 which delivers an output in an appropriate format, as it may be programmed or constructed so to do.

It may at this juncture be remarked that the procedure may experience metamerism, which is to say that different colours may give the same output. Reliance on just three precisely defined wavelengths may fail to differentiate between different colours which react in precisely the same way to those three wavelengths, but which react quite differently - and significantly so - to wavelengths not featured in the

measurement. It has to be borne in mind that by restricting the measurement to three precisely defined wavelengths, information about any other wavelength is inevitably lost. By approximating the three wavelengths as closely as possible to those at which the human eye is the most sensitive, it will clearly be possible to reduce the effect of this loss of information. The fact of the matter is, however, that most colour systems will be readily and accurately measurable by the method and apparatus of the present invention without giving rise to any confusion between different colours.

In process control situations, where known colourants are in use, metameric differences should not occur, and the method of the invention will then provide precise and unambiguous characterisation of colour.

Further information, can, of course, be obtained by adding further laser frequencies or even by adding an ultraviolet frequency (whether laser or not) to the measurement, so that the photodetectors pick up secondary radiation generated by the ultraviolet illumination.

The system is thus extended to become an abridged spectrophotometer. In principle, full determination of metameric properties is thus possible.

The processor 118 is programmable to give an output equivalent to that of conventional colourimeters depending on filtered light.

Further possibilities with regard to the basic system illustrated in Figure 10 will become apparent from the following description with respect to the remaining figures.

Figure 11 illustrates a system in which three lasers 22, 23, 24 contained in enclosures 22a, 23a, 24a illuminate optical fibre end units 22b, 23b, 24b to convey their light via optical fibres 22c, 23c, 24c to illuminate a small region 20 of the object 11 which is examined by optical fibres 25c, 26c, 27c connected to photodetectors 25, 26, 27 of a processor 28.

The optical fibres 22c, 23c, 24c may simultaneously direct light at a single spot on the object 11, the detectors 25, 26, 27 separating out the blue, green and red components by filters (not shown). Or the fibres 22c, 23c, 24c may direct light at adjacent but separate spots on the object 11, which separate spots are examined by the detectors 25, 26, 27 via their optical fibres 25c, 26c, 27c.

Or the lasers 22, 23, 24 may fire at closely spaced but distinct times at the same spot, and the detectors 25, 26, 27 be adapted to receive the light from the spot at appropriate coincident times - or, with further simplification, a single detector can pick up light from this spot, information passing to the processor 28 from the lasers 22, 23, 24 to assing the output of the single detector to the appropriate computation.

It should be noted at this point that the object 11 need not be stationary as illustrated - it might, for example, be a moving textile web, so that measurement is effected continuously or at frequent intervals to generate a continuous record of the

colour of the web. Of course, the object 11 could equally well be a liquid which may be stationary or flowing.

Figure 12 illustrates a system using a tunable laser 32 which, in this instance, is aiming its beams at a liquid cell 30 through which light is transmitted to a detector 35. A controller/processor 38 controls the laser 32 to emit different frequencies at different times and receives information from the detector 35 and correlates such information with the frequency emitted by the laser 32 so as to generate a colour signal indicative of the colour of the liquid in the cell.

Figure 13 illustrates an arrangement in which a single laser 42 or laser system 42 illuminates a wide area of, for example, textile or paper web, via an optical fibre distribution system 43, the resulting transmitted, reflected or scattered light being picked up by a comparable array of an optical fibre system 45 connected to detector/processor means 48, which canscan the illuminated points.

Figures 10 to 13 illustrate, by no means comprehensively, the options available using the laser illumination method of the invention for colourimetry.

Figure 14 illustrates - perhaps even less comprehensively - the availability of the methods and apparatus illustrated in Figures 10 to 13 to be included in a control system such for example as the mixing of paints, the dyeing or printing of textile yarns or webs.

A colouring process 51 affects an object 52 to produce a colour which is illuminated by a laser arrangement 53, light reflected or scattered from it being detected by a detector/controller arrangement 54 that controls the process 51. The process 51 might for example by the mixing of a colourant by the addition to a base of three primary colours and the arrangement 54 may include three distinct feedback loops for the colours.

The colour of a test object may be indicative of the effect of an operation which is not directly concerned with producing a colour, and the invention can be used to monitor or control such an operation. A drying operation, for example, may, if run at too high a temperature produce a colour change which can be detected by apparatus according to the invention which may raise an alarm or alter the temperature or some other process condition.

Whilst it has been noted that the use of a standard illuminant requires exclusion of ambient illumination, it is to be understood that this can be effectively achieved without total exclusion. Laser light can be so bright as effectively to swamp any ambient illumination - though in the case of high-powered lasers it will usually be required to confine the lasers to protect personnel.

Even in the case of low-powered lasers, however, the effects of ambient illumination can be separately measured (as by switching the lasers on and off) and compensated for.

While "colour" has been referred to, it will be recognised that the methods described will also be applicable where one or more or perhaps all of the illuminants are

will play no part, but other considerations may give utility to the techniques herein described in other regions of the spectrum.

Ultraviolet radiation has already been mentioned - infra-red radiation can also be used for a variety of purposes. A scene can be imaged, perhaps convertly, at two or more infra-red frequencies to pick out anomalies, for example objects concealed by camouflage, by a specific response or by a response different from a background. Tunable IR or other lasers could be used to sweep, in the frequency domain, an object or a scene to provide in effect, the plurality of primary illuminants.

CLAIMS

1. A method of extracting information from an object or object scene comprising illuminating the object or scene by a plurality of primary colour illuminants and measuring or recording the resulting light from the object or scene.

2. A method for producing a colour image of an object scene in which the scene is illuminated by a plurality of primary colour illuminants to record colour separate images for subsequent recombination into a true colour image of the object scene by illumination of each with its respective primary colour illuminant, or by one of a set of equivalent illuminants.

3. A method according to claim 2, in which the illuminants comprise lasers.

4. A method according to claim 2 or claim 3, using three primary colour illuminants.

5. A method according to any one of claims 2 to 4, in which the colour separate images are recorded each while the object scene is illuminated by only one of the illuminants.

6. A method according to any one of claims 2 to 4, in which the colour separate images are recorded while the object scene is illuminated by more than one of the illuminants and the images separated by filtration.

7. A method according to any one claims 2 to 6, in which the colour separate images are recorded photographically.

8. A method according to claim 7, in which separate monochrome photographic images are made.

9. A method according to any one of claims 2 to 6, in which the colour separate images are recorded electronically.

10. A method according to claim 9, in which the images are grey-scale images.

11. A method according to claim 9 or claim 10, in which the images are digitised.

12. A method according to claim 11, in which the images are stored in digital form.

13. A method according to any one of claims 2 to 12, in which recombination is effected by projection of transparency images.

14. A method according to any one of claims 2 to 12, in which recombination is effected by scanning modulated illuminant beams.

15. A method according to claim 14, in which scanning is effected by a controlled mirror arrangement.

16. Apparatus for producing a colour image of an object scene comprising a plurality of primary colour illuminants and recording means for colour separate images for subsequent recombination into a true colour image of the object scene by illumination of each with its respective primary colour illuminant.

17. Apparatus according to claim 16, in which the illuminants comprise lasers.

18. Apparatus according to claim 15 or claim 16, comprising three primary colour illuminants.

19. Apparatus according to any one of claims 16 to 18, comprising synchronised illuminants and recording means for recording the colour separate images each while the object scene is illuminated by any one of the illuminants.

20. Apparatus according to any of claims 16 to 18, comprising filter means separating images from more than one simultaneously operating illuminants.

21. Apparatus according to any one of claims 16 to 20, in which the recording means comprise photographic recording means.

22. Apparatus according to any one of claims 16 to 20, in which the recording means comprise electronic recording means.

23. Apparatus according to any one of claims 16 to 21, comprising transparency image projection means in which the primary colour illuminants project images of the colour separate images in register on to a screen.

24. Apparatus according to any one of claims 16 to 21, comprising illuminant beam scanning and modulating means scanning and modulating illuminant beams to form colour separate images in register on a screen.

25. Apparatus according to claim 24, said scanning and modulating means comprising a controlled mirror arrangement.

26. A method for measuring colour comprising illuminating a test object with laser light of different wavelengths and measuring the resulting light from the test object.

27. A method according to claim 26, in which three laser light wavelengths are used.

28. A method according to claim 27, in which the three wavelengths are in the blue, green and red spectral regions.

29. A method according to any one of claims 26 to 28, in which the test object is illuminated, and the resulting light measured, simultaneously by two or more of the laser light wavelengths.

30. A method according to any one of claims 26 to 29, in which the test object is illuminated, and the resulting light measured, successively by individual laser light wavelengths.

31. A method according to any one of claims 26 to 30, in which the test object is illuminated with ultra-violet light, and any resulting secondary emission measured.

32. A method according to any one of claims 26 to 31, in which both incident and reflected light beams are measured.

33. A method according to any one claims 26 to 32, in which a calibration is made by measuring zero illumination and 100% (i.e. direct) illumination.

34. A method according to any one of claims 26 to 33, in which the measurements are made with the brightness of each laser light source remaining the same relative to the other laser light sources.

35. A method according to any one of claims 26 to 33, in which the measurements are made with the brightness of at least one laser light source being varied and compared to that of another.

36. A method according to any one of claims 26 to 35, in which light from at least one laser light source is guided to a measuring point by a optical fibre.

38. A method according to any one of claims 26 to37, in which measurement is made at two or more locations by optical fibres terminating at those locations.

39. A method according to any one of claims 26 to 38, used as an element of a colour control process.

40. A method according to claim 39, in which measurement of light from a test object illuminated by laser light is used in a feedback loop.

41. Colour measurement apparatus comprising laser illuminant means capable of different wavelengths and light measuring means measuring light from a test object illuminated by said illuminants means.

42. Apparatus according to claim 41, comprising three laser illuminants of different wavelengths.

43. Apparatus according to claim 42, in which the three laser illuminants have wavelengths in the blue, green and red spectral regions.

44. Apparatus according to any one of claims 41 to 43, comprising an ultra-violet illuminant.

45. Apparatus according to any one claims 41 to 44, comprising individual channels for each wavelength.

46. Apparatus according to any one claims 41 to 45, comprising a common channel for two or more wavelengths.

47. Apparatus according to claim 46, comprising time sequencing means for different wavelengths sharing a channel.

48. Apparatus according to any one claims 41 to 47, comprising channel means for one or more wavelengths comprising optical fibre means.

49. Apparatus according to any one of claims 41 to 48, comprising optical fibre means distributing measuring light from a common source to a plurality of measuring parts and/or from a plurality of measuring parts to common measuring means.

50. Colour control means comprising apparatus according to any one of claims 41 to 49.

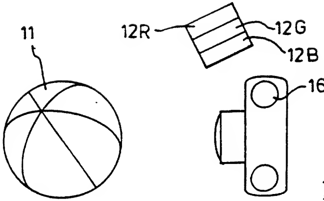

FIG.1

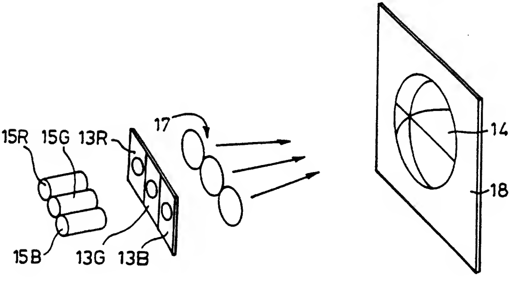

FIG.2

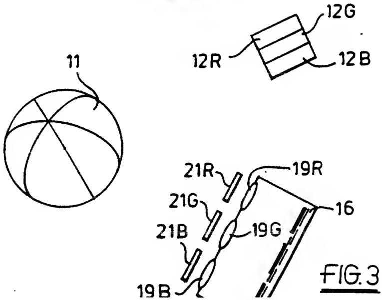

FIG.3

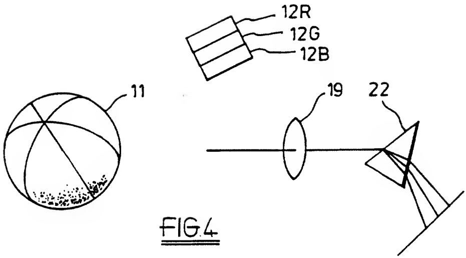

FIG.4

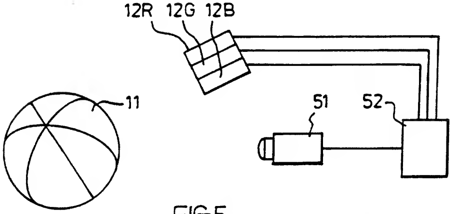

FIG.5

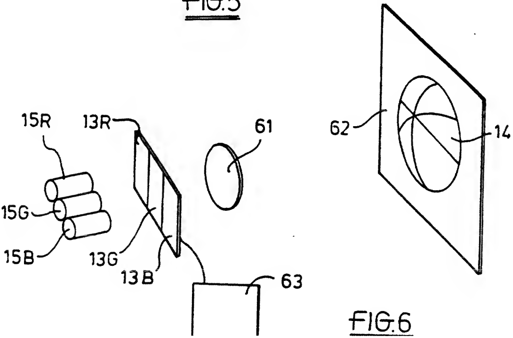

FIG.6

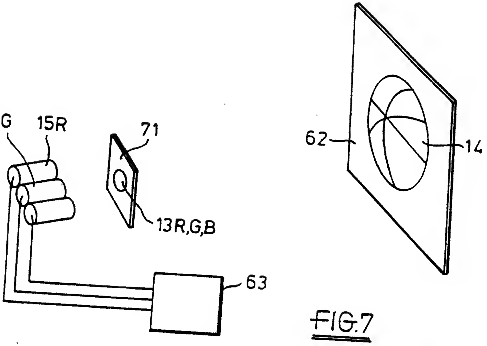

FIG.7

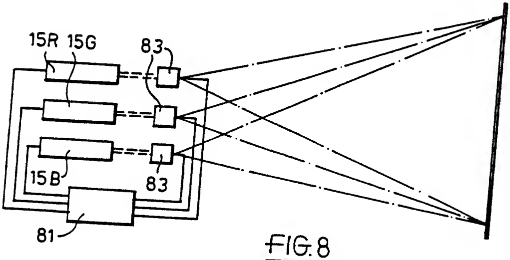

FIG.8

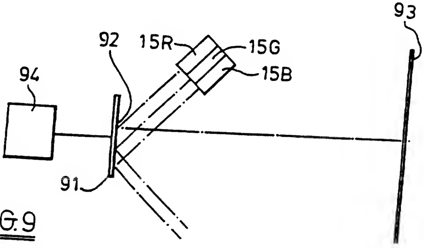

FIG.9

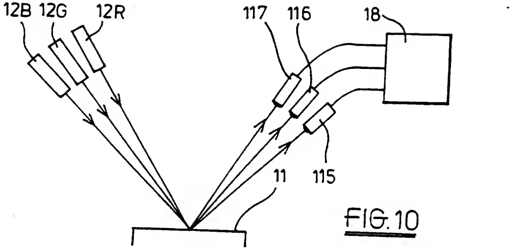

FIG.10

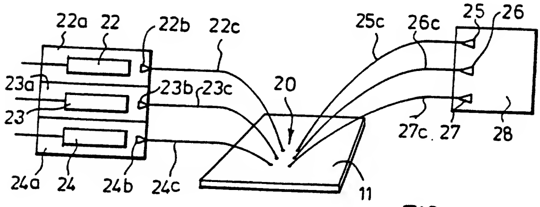

FIG.11

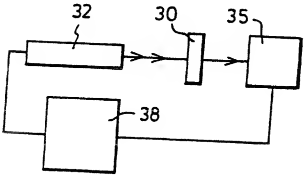

FIG.12

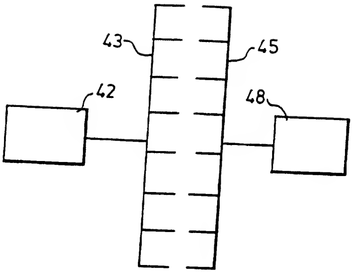

FIG.13

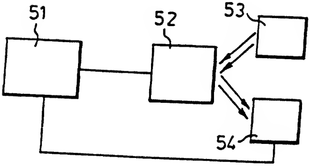

FIG.14

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 95/01789

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04N1/48 G01N21/25

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,92 04859 (KAAKINEN) 2 April 1992 see abstract see page 4, line 14 - line 24 see page 6, line 19 - line 32 see figures 1,2 ---	1-4,6-8, 16-18, 20,21, 26,27, 29,41, 42,44

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
23 November 1995	08.12.95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Thomas, R.M.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 95/01789

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,5 264 925 (SHIPP) 23 November 1993	1,2,4,5, 9-12,14, 16,18, 19,22
	see column 1, line 8 - line 24 see column 2, line 59 - column 4, line 18 see column 4, line 33 - line 38 see figure 1 ---	
X	EP,A,0 597 696 (NIKON) 18 May 1994	1,2,4,5, 9-12,16, 18,19,22
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X	US,A,5 001 556 (OLYMPUS OPTICAL) 19 March 1991	1,2,4,5, 9-12,16, 18,19,22
	see abstract see column 4, line 33 - column 5, line 30 see column 6, line 13 - line 24 see column 6, line 48 - line 51 see column 30, line 41 - line 47	
A	see figures 1,3 ---	36,48
X	US,A,4 854 692 (KOBAYASHI) 8 August 1989	1-3,6,9, 16-18, 20,22
	see column 1, line 5 - line 42 see column 6, line 33 - line 60 see column 8, line 16 - line 26	
Y	see figure 1 ---	26, 29-31, 36,41, 44,46-48
Y	US,A,5 053 626 (TILLOTSON) 1 October 1991	26, 29-31, 36,41, 44,46-48
	see column 3, line 36 - line 48 see column 4, line 13 - line 26 see column 5, line 53 - line 66 see column 6, line 56 - line 62 see column 8, line 44 - line 46 see figure 1 ---	

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 30, no. 4, September 1987 NEW YORK US, pages 1647-1649, ANON 'Multiple-image vision inspection process' see the whole document	1
A	US,A,4 978 202 (YANG) 18 December 1990 see abstract see column 2, line 17 - line 57 see figure 1	14,15, 24,25
P,X	US,A,5 408 268 (SHIPP) 18 April 1995 see abstract see column 2, line 53 - line 58 see column 2, line 66 - line 68 see column 4, line 20 - line 36 see column 8, line 36 - line 41 see figures 1,2	1,2,4,5, 9-12,16, 18,19,22

International Application No
PCT/GB 95/01789

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		WO-A-	9400954	06-01-94
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US-A-4978202	18-12-90	NONE		
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		US-A-	5394187	28-02-95